TANGIBLE USER INTERFACES IN ORDER TO IMPROVE COLLABORATIVE INTERACTIONS AND DECISION MAKING

Alessandra Scotta
Geodan, President Kennedylaan 1,
1079 MB Amsterdam, The Nederlands

Henk Scholten
Spinlab, Free University Amsterdam
C.E.O. Geodan
President Kennedylaan 1,
1079 MB Amsterdam, The Netherlands

Sisi Zlatanova
Delft University of Technology
Jaffalaan 9, 2628 BX Delft, The Netherlands

Erik van Borkulo
Geodan, President Kennedylaan 1,
1079 MB Amsterdam, The Nederlands

ABSTRACT: The paper introduces a research based on an innovative multi-user tangible interface system that aims at introducing an instrument to improve the response phase of the decision-making process. The purpose is to set up and develop a decision support system to overcome some of the problems that are still causing inefficiency in the decision-making process and analyze the reactions of users upon the new introduced technology.

The paper consists of two parts The first part of the describes theories upon which the research project is based, explaining why and how a multi-user tangible interface can help collaborative communication during crisis response, the challenge, the chosen solution and the architecture. The second part describes how the presented solution will be tested to prove if the new system will be useful and accepted by users.

KEYWORDS: response phase, collaboration, visualisation

1 INTRODUCTION

Natural en man-made disasters are since always constantly a part of human beings life and humans will never be completely protected from them. Terrorists attacks, floods, earthquakes, heavy weather conditions, accidents caused by chemical industry, wildfires will continue to be part and strike our lives. Risk prevention can help to predict and prevent dangers in order to reduce the undesired and tragic effects resulted by human accidents and natural calamities but it will not entirely defend human lives. What can and strongly needs to be improved is the manner to respond to disasters. Quick response time, good collaboration and coordination between involved parties, advanced techniques, resources and infrastructure are essential features to handle disasters and consequently to guarantee more safety to citizens. Currently the respond to disaster is still not efficient and well-organized and therefore inducing elaborated studies, researches and analysis on the item.

The inefficiency during a response can be related to the following main reasons (van Borkulo et al, 2005, Diehl and van der Heide 2005, Diehl; et al, 2006):

- Lack of proper systems (hardware and software);
- Not enough collaboration between involved parties;
- Lack of real-time information of the area of the disaster (this point is related to the previous one);
- Geographical data (and non) not available or not immediate reachable because of political and security reasons;

- Not enough standardization at the data level, causing the share of data between different systems difficult or even impossible;
- Not enough standardization in the communication between involved systems, causing the impossibility of a distributed infrastructure.

In this paper we present a multi-user tangible system, open and based upon concepts as interoperability and standards, which intends to improve collaboration and coordination between parties involved in crisis responses. The following sections introduce the risk management phases and discuss factors specific for response phase. Afterwards the concept of multi-user tangible interfaces is presented; we describe the solution we have chosen and the architectural principles. The last part of the paper describes the assessment of the system, based upon a definition of a case study where a live of the system is performed and a quantification of the acceptance of the system.

2 PHASES IN DISASTER MANAGEMENT

Disaster management aims at reducing or avoiding potential losses from hazards, assuring prompt and appropriate assistance to victims of disaster, and achieving rapid and effective recovery (Orchestra, 2006). The goals of disaster management could be described as (Kevany, 2005):

- Reduce, or avoid, losses from hazards
- Assure prompt assistance to victims
- Achieve rapid and effective recovery

Disaster management is an ongoing cyclic process that could be divided into the following four phases (figure 1):

1. The *prevention and mitigation phase* that aims to eliminate or reduce the probability of disaster to occur or aims to minimize the effect of a disaster in case the disaster is unavoidable. Examples of mitigation measures are vulnerability analyses updates, zoning and land use management, building use regulations and safety codes, preventive health care and public education.
2. The *preparation phase* aims to prepare a plan on how to respond to a disaster. Preparation measures include preparation plans, emergency exercises/training, resource inventories, emergency personnel/contact lists, mutual aid agreements and public information and education.
3. The *response phase* is the "provision of assistance or intervention during or immediately after a disaster to meet the life preservation and basic subsistence needs of those people affected by the disaster'' (http://www.eu-orchestra.org/).
4. The *recovery phase* aims - to return to a normal situation, for instance by building temporary housing and providing medical care.

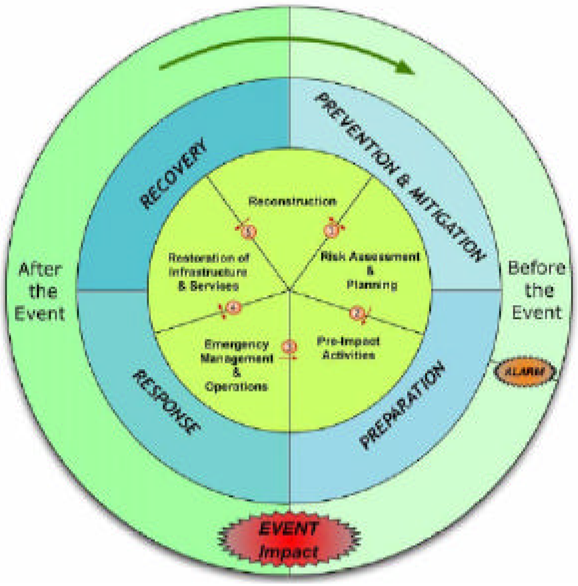

Figure 1: The risk management cycle, source [1]

The paper addresses how collaboration between involved disciplines can be improved during the *response phase* of a disaster.

3 THE RESPONSE PHASE

3.1 Time and stress

During the crisis response phase, the main factor to be considered is time. Involved agencies take decisions rapidly, under stress conditions and often they have more confidence on human beings opinions rather than on existing computer systems. The reason often mentioned is that if the system is unfamiliar to the users, they prefer to rely on their own judgments rather than on a tool that as first impact is unknown for what concerns interface as well as functionality.

The Technology Acceptance Model (TAM) theory presented by Davis in 1989 describes the factors determining the acceptance or rejection of a new technology. Davis says that a system acquires added value and therefore it will be accepted between end users if it satisfies two features: the perceived usefulness (PU), defined as the degree to which a person believes that using a particular system would enhance his or her job performance, and perceived ease of use (PEOU), defined as the degree to which a person believes that using a particular system would be free from effort (Davis, F. D. 1989). The two rules, applicable to developing tools in general, are even more critical for systems used in risk management. Under stress, people do no use a system if they do not immediately perceive its usefulness and if they do not quickly understand how to use it. Therefore they rely on human decision-making, which is result of human perceptions and reflections rather than produced by artificial intelligence. As consequence, a major issue for systems to be used during the decision-making phase is that they should have an easy and intuitive interface inducing people to be confident with the application.

3.2 Collaboration and coordination

The second major factor to be considered in the response phase is collaboration between the emergency services involved in risk management, such as fire brigade, police, paramedics, civil protection. Coordination can be different, e.g. between: members of the same sector, different sectors, units operating on the incident location and teams usually situated in a regional office. All communication and coordination needs to be optimal in order to have the incident under control and guarantee protection to citizens.

At present, in most of the cases, each sector works independently, on different systems, exchanging data in inefficient ways, causing loss of time and information. Reasons are complex and of different nature, they can be shortly summarized in: difficulties of reaching and sharing essential data, inadequate infrastructure to facilitate communication between parties, communication not orchestrated according standards, lack of adequate innovative technology devices.

The coordination is also very intricate because of the complex organizational structure, the different disciplines engaged (and their different nature) and the manner of operating. Observations and evaluations from practices show that due to lack of optimal coordination, the collaboration between the different disciplines is insufficient and could be improved. In the Netherlands, the level of command, control and coordination between the different disciplines is structured in multiple levels in the organization defined by a GRIP (Coordinated Regional Incident Suppression Procedure). The necessity to activate one or more levels depends from the severity and extent of the accident. The disaster response organization is a scalable organization that increases or decreases according to the accident level. The lowest level (GRIP0) is the operational level where emergencies services are on the location of the accident, take the necessary measurements, control and coordination and eventually, if the incident can not be resolved and extended, scale to a higher level. Explanations of these levels are givens elsewhere in the literatures (van Borculo et al 2005, Diehl et al, 2006). The increase of the level is proportional to the increase of collaboration and communication between the teams and units and as consequence to the complexity of the coordination.

Our contribution intends to analyze and decide which tasks could be helped and improved at the tactical level. The idea is to introduce a modern tool that helps the R.O.T. to:

- better cooperate between head of each discipline (cooperation task)
- take the right decisions reducing time (supervision task)
- coordinate actions of field units (coordination task)

4 THE CHALLENGE

Actually, present available systems architectures and applications used in the response phase are not evolved enough to facilitate and to speed up the processes. Different research projects have proved that lot of work needs still be carried out. The challenge is the development of a collaborative tool to be used by the different actors in emergency management, for example, the Regional Operational Team (R.O.T) gathered around a table placed in a fixed location. Such a collaborative tool can facilitate decision-making and cooperation between all the involved units. In the choice and development of a collaborative tool, the following aspects have been taken into account:

1. Use of spatial-Information
It has been studied and confirmed that use of geo-information in disaster management is essential to develop powerful tools to facilitate and assist tasks and to be integrated within the system architecture (Cutter et al 2003, Neuvel et al. 2006). Especially during crisis responses geo-information is essential to understand the situational and context awareness of the incident. When a flood takes place, for instance, questions will rise on where the dikes have collapsed, which areas have been flooded, which areas are expected to flood, which areas have to be evacuated, what roads are still accessible and which ones are not? These and other questions, have one thing in common: they all contain a spatial component. They are all referring to a specific geographic location (e.g. www.gdi4dm.nl/index.cfm?segmentnr=3). Not only maps in two dimensions, but also three dimensional representation of the reality, images, video's, etc. help to have a complete picture of the involved location and surroundings (.

2. Advanced visualization within collaborative interactions
Not only the kind of geo-information, but also its visualization is an important aspect to be considered for collaborative interactions during the response phase. Within collaborative interactions, participants usually gather together, cooperate, interact with computers via input devices such as mouse's and keyboards and evaluate information represented and displayed in output devices, such as monitors and wall papers. Geographical data is still displayed on a monitor of a computer of projected on a wall, but often these traditional methods of visualising geographical information do not any longer satisfy the needs of the users, especially not when collaboration between different parties is a main issue.

The concept of tangible user interface (TUI) seems the ideal solution for discussion groups. The system should have an input layer on top of a table which is tangible to participants. Users interact directly with the table surface and the system reacts to the user's request projecting a new representation of the information on the table (Scotta' et al. 2006).

Studies over TUI's in the form of tabletop in order to improve collaborative interactions have been already performed since many years ago. These tools can be utilized not only in disaster management, but also in other disciplines, such as education, spatial planning or participatory systems. The idea of presenting geographical data on a tabletop instead of on a computer screen or on a wall is not new, various systems have been already developed using different technologies, but still they are in a prototype form or seldom used. The reasons could be numerous either these prototypes have been developed by research organizations for the sake of research, or that existing applications running on tabletops are still not very intuitive, or people could still not understand the value of the systems because software functionality do not satisfy their requirements or because they are still bounded to traditional systems.

Keeping in mind the considerations illustrated above, the system to be employed during the response phase by responsible people of the different emergency units should have the following features:

1. the system has to be more innovative with respect to existing solutions;
2. the interface application has to be developed based on primary end user's requirements:
    - intuitiveness;
    - easy to use;
    - no special training required;
    - supportive in collaborations between members involved;
    - advanced in the visualization of spatial information for situational awareness;
    - easy human-system interaction (direct input device);
    - possibility to perform tasks in parallel (multi-user aspect);
    - can be used daily;

One of the first matters to be considered is the interaction human-system. Users around the table should interact with the system directly and not using input devices, such as mouse's or keyboards. The information displayed on the table

should become tangible for the users, allowing them to retrieve information with a direct contact on the table (Scotta' et al. 2006). The conversation becomes more natural, clearer and there is less hesitation in interacting with the system.
The system should permit multiple users to work together and in parallel when gathered around the table. The multi-user quality introduces an original and unusual aspect to the system since the current hardware and software is still based on single user input and as consequence users are not aware of the advantages that can be derived from a multi-input tool. Investigation concerning multi-user functionality becomes an important element of the research: which functionality can be developed to support multiple users? For example, how do we handle multiple navigation functionality such as zoom in, out and pan? The goal is to introduce a system which is touchable to users but also recognizes who has touched where and when and therefore responses to the who, where and when questions.

5 THE SELECTED TECHNOLOGY

For the scope of the research the DiamodTouchTable has been chosen as multi-user tangible interface. The system, developed by the Mitsubishi Research Labs (MERL, www.diamondspace.merl.com) recognizes when a user touches on the table, the touched location point and who touched the specific point. The user interacts with the table directly with the hands and the system distinguishes not only who touched where, but also which kind of interaction occurred, the gestures of the user, e.g. touch with a finger, touch with two fingers, double touch, touch with fist. Figure 2 shows the interface of the table and two users requiring information in two different locations at the same time.

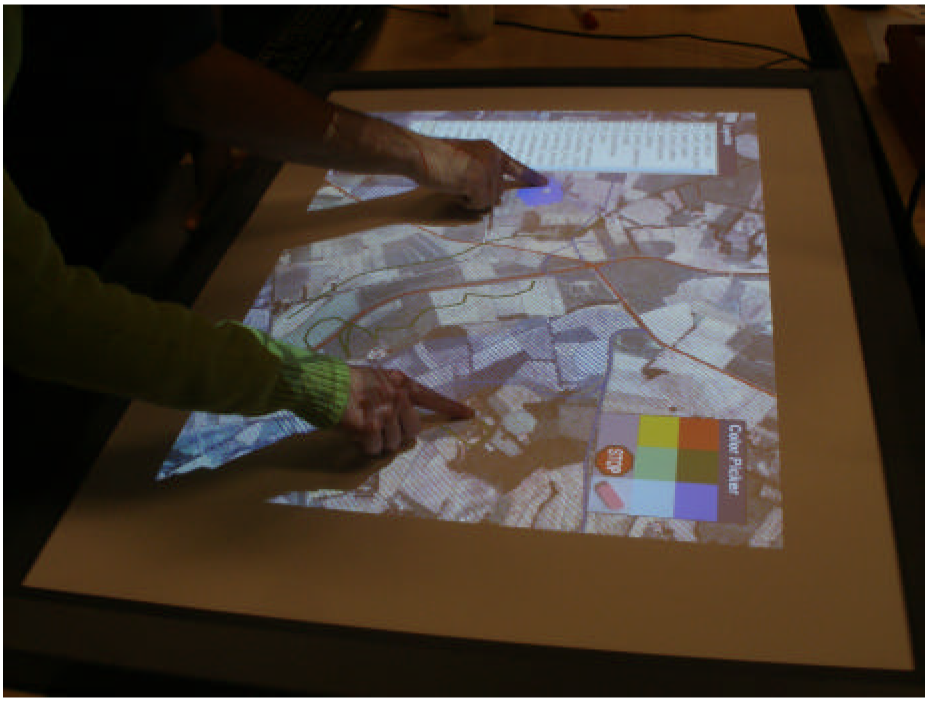

Figure 2: The multi-user system interface

The detection of a specific user and of an explicit gesture is achievable thanks to the structure of the table. The top of the table generates electric signals which are location dependent and different from each other. The signals are capacitive coupled to receivers through body of the user and sent to a computer connected to the table (Dietz et al.). Figure 3 shows an example of signals generated by the contact of two users with the table surface. The strength of the signal is proportional to the area touched by the user: the red user generates a wider signal than the green user probably because the first one places a fist and the second just a finger on top of the table.

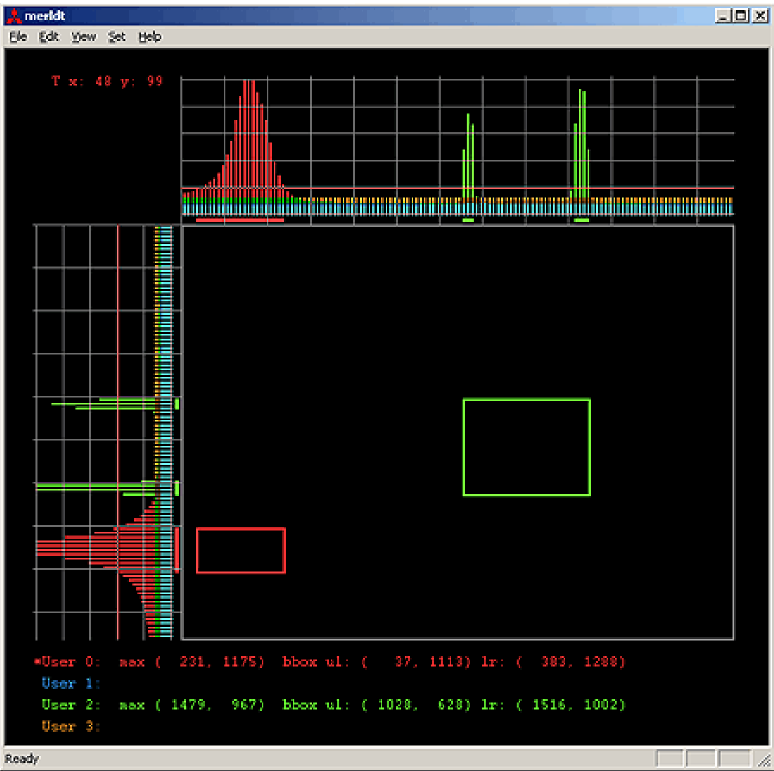

Figure 3: Signals generated by two users on the Diamond Touch

The key features of the system are: (Ryall 2002)

- Multi-point: multiple simultaneous touches from one or more users
- Identification: who is touching each point
- Debris Tolerant: objects on the table do not interfere with operation
- High Resolution: sub-pixel resolution
- Unencumbering: no special stylus to learn or lose
- Inexpensive: Compares favorably to less capable technologies

The DiamondTouch concerns only the hardware part of the system, software is still a research prototype. MERL hopes to collaborate with companies and universities in order to develop software for their innovative technology. Currently Geodan B.V., the SPINlab of the Vrij Universiteit of Amsterdam and MERL have joined forces to develop software upon the DiamondTouch in order to prove that the complete product could be a useful tool for different fields. Especially within crisis response, we are convinced that the multi-user functionality is an advantage to work in parallel during the decision making-process where time is a main issue. The multi-touch and multi-user feature is to our opinion the added value of the selected technology with respect to other tangible interfaces based on touch screens or any other single-input interface.

Part of the research project described in this paper deals with the design of a software architecture and with the development of a software upon the DiamondTouch. The architecture towards an open and distributed system is described in the following section.

6 THE ARCHITECTURAL PRINCIPLES

One of the major problems during the decision-making process of an emergency response is the inability to properly communicate between the involved systems and the difficulty to reach and use geographical data that would assist and facilitate decisions. The first issue derives from the fact that the concerned systems are independent from each other and designed with a decentralized autonomous architecture. Each of them runs on a specific platform, which is built upon specific software and uses data mainly stored locally and of a specific format. The lack of geographical data is a consequence of the first problem: difficulties do not arise only because of political and administrative reasons but also because data are stored in different formats in isolated systems and therefore are per definition not easily sharable. The only way to share data between two systems is via conversions from one format to another, causing loss of information. Definitely, such architecture is not the proper one within disaster management.

Even a centralized architecture, where data is stored in a central database and clients share geographical data is not the right approach during crisis responses because usually data is stored and managed independently by each organization and it will be not realistic to think to a centralized database. Organizations work independently and each has distinct authorization upon their datasets. Furthermore, a centralized system runs the risk to end up with outdated data sets.

In this respect, appropriate Spatial Data Infrastructure (SDI) and collaborative interactions is increasingly considered a critical aspect of decision making in disaster and risk management (Scotta' et al. 2006). One of the characteristics of the SDI which should be built for risk management should focus on the following essential aspects: standardization, distribution and interoperability. Plans for the development of infrastructure that consider as fundamental the mentioned aspects have been already started. At European level, the Orchestra project, for example, is designing and implementing the specifications for a service oriented spatial data infrastructure for improved interoperability among risk management authorities in Europe (http://www.eu-orchestra.org/). The Orchestra architecture is open and based upon standards. Concepts as service oriented architectures (SOA), web services based upon main standards (e.g. ISO, OGC, W3C, OASIS) are hot topics in the information and communication technology (ITC) world as well as in the geo-information world and are also the right solution towards an interoperable infrastructure to be implemented in different fields, in particular in disaster management.

Also for what concerns the DiamondTouch table, the ideas around the system architecture are based upon the use of web services (e.g. SOAP services, web mapping services), use of standard communications protocols between client and services and use of open source solutions for the development of the multi-user client application on the table. In other words, a system opened to distribution and interoperability and which fits with the ideas proposed by the Orchestra project.

The client will be developed taking into account the interaction user-table. The interface should be very dynamic: if a user approaches or touches an object on the table, the response of the application should be immediate and active, the objects highlights, flashes or displays interesting information. Consequently, the reactions of the table to users' touches should result into dynamic behaviors and not as passive as happens in the traditional interfaces on computer screens. Figure 4 shows the main components of an architecture that is open, distributed and according to the standards.

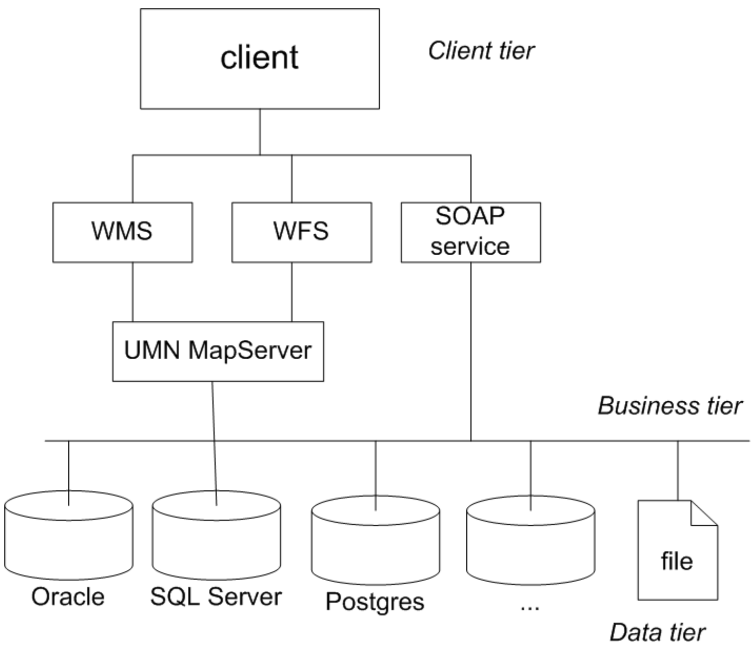

Figure 4: Architecture for the multi-user system

7 ASSESSMENT OF THE CHOSEN SOLUTION

An assessment of the decision making process with the use of the described multi-user decision making system (DSS) has been already planned and defined. The evaluation consists in two steps:

1. A definition of a case study
2. A quantification of the acceptance of the system

4.1 A definition of the case study

To prove the approach described above, a disaster simulation is planned in the Netherlands in October 2007. The disaster will take place along the rail track which connects the port of Rotterdam to the places Zevenaar/ Emmerich at German border (Betuwespoorlijn). The rail track is used exclusively by goods trains and it is meant to easily and quickly transport materials from the port of Rotterdam towards European inner lands.

The scenario is the following: a train is derailed at a specific kilometer and fire breaks out. The main railway office sends an alarm to the alarm room of region Gelderland Midden. The operational units (fire brigade, ambulances and police) are alarmed and sent to the location where the accident occurs where different railway wagons are derailed and crashed.

One wagon, laded with ethanol, leaks and fire starts to break out and fluid material runs off of the wagon threading the other derailed wagons. The disaster is classified with the first level of emergency. During the exploration of the severity of the accident a big explosion takes place and a violent cloud starts to spread around throwing pieces of material all around. Different wagons are involved and the big smoke clouds increases. The commandant of the fire brigade notices the victims between the help units and at this point he escalates the severity of the level of the incident to the second level. At this point the Coordination of disaster area and the R.O.T take the responsibility for decision-making. The multi user system is located at the office where the R.O.T. is gathered and used to execute specific tasks involving supervision, control and coordination during this phase.

Geo-information visualization

The area where the incident has occurred is automatic visualized on the table and the necessary geo-information is automatically displayed. Geo-information data consists, for example, of:

1. Thematic digital maps, such as for example road maps, water points maps, demographic maps, maps representing the risks objects in the area (e.g. tank stations, chemical companies), the objects which could be effected by the risk's objects causing further damages or victims (e.g. schools, houses, hospitals), photo's of the location.
2. Background maps: maps used only as reference by users. Examples of these maps can be: satellite images, topographic maps, etc.
3. Real-time data: the table displays the real-time location of the units at the location of the incident. Each type of operational type of unit (fire brigade, ambulances, police) is identifiable by a specific symbol immediately recognizable by the officers around the table;
4. Temporary event maps: these maps represent temporary events, such as presence of big concerts, heavy traffic jams, big reunions, etc. in the area of interest, which need to be taken in consideration during the decision making process;

Using this information the decision-makers can better understand the context of the incident and share more effectively information between the actors gathered around the table. Officers can better supervise *(control)* the area and the operational units and answer to specific questions, such as: where are the nearest hospitals? What is their capacity? Which is the nearest water point? Which is the number of people living in the area? How many children and elderly people living in the area? The table can definitely help to perform better and more efficiently command and coordination tasks.

Track and trace task (command and coordination)

Displaying real time data of the units on location, officers around the table can easily perform coordination and command tasks. Each officer can follow his units on the table and control if each unit is on the exact spot (mobile track and trace system).

Also command tasks that are sent from officers around the table to units can be preformed with the system. A "*move to command*" is a typical example. If a unit needs to be moved, the officer can select the unit in question touching the corresponding symbol with a finger on the table, send (via GPRS or UMTS) a message to the unit in order to let him know that he should be ready for a specific command. Afterwards the officer could point to the exact location on the table where the unit should move to and the geographic location will be instantly sent to the unit that is waiting for the command and automatically entered in his navigation system that will bring him to the right spot. Because of the multi user aspect of the system, each officer can send commands to his units independently from the work carried out at the same moment by another officer around the table. Coordination and command tasks are performed in parallel saving time that could be crucial during this phase of crisis response. The "*move to command*" described is just an example of direct and parallel communication from the R.O.T. to the operational units. Of course, any kind of information can be sent from the table system to the mobile system present by each unit.

In the simulation of the accident a toxic cloud spreads in the areas around the incident and an organization to measure the quantity of the spread substances is sent to diverse spots with special measurement devices ('*measure and observe'* process). The measurement spots are calculated and selected based on input data, e.g. the wind direction and the wind speed. Measurements results are sent to the R.O.T. that will base decisions also on the received results. On the table the officer in charge for the coordination of the measurements units can calculate the location where measurements need to be taken with a function directly available on the table, send the *"move to command"* to each unit and wait for the results that can be sent to the tabletop system from each unit. Received information can immediately be displayed on the table and shared between participants.

The tasks mentioned above are planned to be experimented during the disaster simulation of the Betuwespoorlijn.

7.1 Assessment of decision making process with multi-use system

Starting from the results acquired during the exercise planned in October, we intend to understand if the introduced system will really contribute to solve some of the current obstacles present during the decision making process, and if the system will be accepted by end users.

Interviewing end users and people aware of the complex aspects involved in the response phase of risk management, the main issue is to realize if the system helps during the process, getting reactions to the following arguments:

- Technical: this aspect involves the inventory of eventual technical problems encountered during the use of the system, e.g. software and hardware limitations still present in the system, acceptability of the performances of the system, limitations in the communication with mobile units.
- Data: this aspect concerns the availability of the data and if the data satisfies the needs. Questions such as *"Is geographical data immediately reachable? Is real-time data sent from mobile units easily available? Which data was not available or reachable but essential for during the process?"* should get an answer.
- Methodology: this aspect involves the influence of the system from the methodological point of view during the process. Questions such as, *"Is collaboration between users improved or are conflicting methods or approaches in using the system? Are coordination methods between the different services improved? What is missing in the system that could bring an additional improvement in the process?"*

When introducing a new technology changes can influence the organizational structure as well the way people work. The prediction of the user acceptance of the new technology gives a good indication for the (un)successful introduction of the new system. The TAM model will be used to give empirical evidence on the relationships that exist between usefulness, ease of use and system use.

We believe that if users find the system easy to use and useful in their work, all the limitations technical or methodological related can be overcame. Users will be questioned to evaluate their perceived ease of use and perceived usefulness on the system. According to the theory of Viswanath Venkatesh and Fred D. Davis (Viswanath et al.), the following two types of processes significantly influence user acceptance and therefore will be taken into account when interviewing the users:

- social images processes such as, voluntary or mandatory use of the system, subjective norm (or the person's perception that most people who are important to him think he should or should not perform the behavior in question) and image (or the degree to which use of an innovation is perceived to enhance one's status in one's social system);
- cognitive instrumental processes (job relevance, output quality, result demonstrability, and perceived ease of use);

Also the factor experience will be taken into account when evaluating the perceived usefulness of the system. Users will be interviewed when having no experience, but also after having trained on the new system.

8 CONCLUSIONS

Based on our experiences we think that the use and development of multi-user tangible systems can be a strategic way to improve collaborative interactions in every phase of disaster management, from risk prevention to response. We firmly believe the system will help decision-makers by ensuring better collaboration and coordination between the involved emergency services, such as paramedics, police, fire brigade, civil protection and will improve and speed up the decision making process during risk management.

A project has been started, an architecture based upon concept as standardization, distribution and interoperability has been defined, software developments has been started, the system will be tested during a disaster simulation planned in the Netherlands in October 2007 and its usefulness and users acceptance will be assessed.

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